Understanding an Irrigation System: Pressure and Flow

Introduction

Water is essential to nursery production and landscape maintenance. Irrigation systems are used to water plants and the person watering plants should have some understanding of water flow, pressure, and friction loss in order to utilize the system to advantage. This chapter covers the basic hydraulics or the basic principles of how an irrigation system works. You might be familiar with hydraulic systems on tractors or other equipment where a hydraulic pump generates the fluid flow (hydraulic oil) to power equipment. Hydraulics is a science that deals with fluid flow in pipes or hoses and the pressure (force or energy) that powers equipment. We must move water under pressure in a piped system to distribute it to sprinklers, spray stakes, or drippers. The goal of this chapter is to make you similar with pressure, friction loss and pipe flow terms.

Let's start with the example in Figure 1. In a nursery or in a landscape, have you seen 100 foot garden hoses running out to a "Y" connector and from there two 100 foot hoses going to two 4 gallon per minute (gpm) sprinklers? Do you see anything wrong with this picture? Maybe not, but read on. Water flow in a pipe or hose is influenced by several things:

- Velocity of the water in the hose causes turbulence as the water tumbles and rolls over the pipe inside surface.
- Energy loss due to the water drag across the roughness of the inside surface of the hose or pipe means a drop in the water pressure (pressure is energy).
- Distance the water flows in a pipe – the accumulation of the energy loss increases over distance.

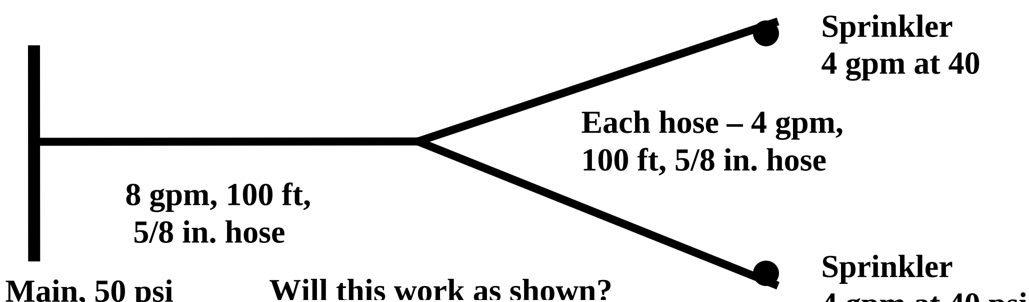

Figure 1 – Example of high pressure loss situation. Garden hose is carrying too much flow.

In the above situation, there is a garden hose, maybe 5/8 inch in diameter, carrying water some distance to sprinklers. The water required at the sprinklers is 2 sprinklers times 4 gpm each or 8 gpm. This water must flow through the first 100 feet of hose and then, after the Y connector, 4 gpm flows through each of two hoses to a sprinkler.

A flow of 8 gpm is a large flow rate for a 5/8 inch garden hose so the water must move through it at high velocity. The high velocity over 100 feet of length means a large energy loss called friction loss. In fact from a friction loss chart one can find that an 8 gpm flow for 100 feet

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causes a loss of 14.3 psi of pressure. Even 4 gpm for the next 100 feet means a loss of 4 psi. By the time the water gets to the sprinkler head, the energy loss is 18.3 psi.

If the sprinkler was to operate properly at 40 psi and the main line supplied the water at 50 psi, then the 50 psi minus the friction loss of 18.3 psi leaves only 31.7 psi of pressure at the sprinkler. The sprinkler nozzle works properly at 40 psi so at 31.7 psi it will not do as well. Expect the water distribution to be poor. At a low pressure the water does not break up very much (stays as large droplets or a stream) in passing through the nozzle and the wetting pattern will look like a donut around the sprinkler head, not very uniform in distribution.

The water coming out of the nozzle at low pressure falls more heavily in one part of the circle as the sprinkler rotates, making a donut-like extra wet area (Figure 2). At too high a pressure, the water comes out in small droplets or a mist and tends to fall close to the sprinkler head. At the proper pressure, there is a good mix of droplet sizes so the distribution patter is good. Of course, more water will fall close to the sprinkler head than far away and this is the reason sprinkler heads must be overlapped to get uniform distribution.

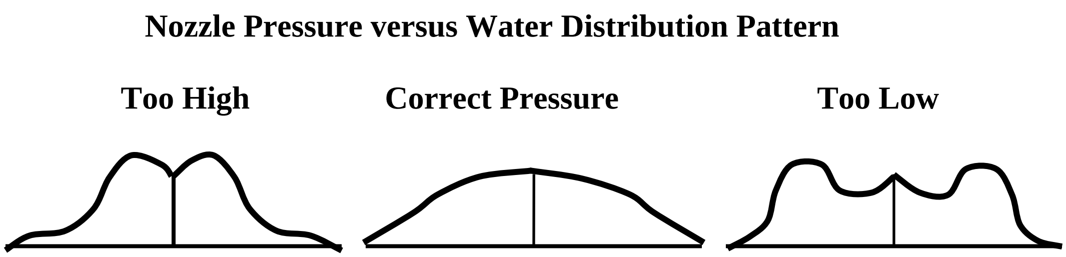


Figure 2 – A nozzle works best at a specific pressure. Distribution is poor at too high or too low pressure. Overlapping the sprinklers correctly gives a uniform watering pattern.

A larger pipe would improve this situation. For example, replacing the garden hose with a ¾ inch polyethylene pipe, the pressure loss would be about 7.5 psi in total and likely the sprinklers would work okay because the pressure at the sprinkler would be 50 psi (pump pressure) minus 7.5 psi friction loss equal to 42.5 psi which is close to the proper sprinkler pressure for this example. Using a 1 inch polyethylene pipe would lower the pressure loss to 2.3 psi. This tells us that using a larger size pipe lowers the water velocity and lowers the friction loss (energy loss in psi). Slower flowing water moves over the roughness in the pipe in a gentler manner and does not drag against the pipe walls.

Water pressure affects the performance of a sprinkler nozzle or a drip emitter. **Pressure is perhaps the most critical factor in proper irrigation system operation**. An irrigation system should be designed to apply water uniformly over the entire area. Uniform pressure is important for uniform application from a series of nozzles and emitters on a pipe line.

While this chapter will focus on pressure, flow and friction loss, another issue not covered here is water management and efficient use of water for production and maintenance. Nutrient management is affected by watering. Nutrients are soluble so water management becomes a critical part of nutrient management. Proper operation of an irrigation system will improve water and nutrient management. Learning to operate the irrigation system to deliver the correct amount of water is important. Overwatering will result in leaching the nutrients out of the plant root zone.

Pressure

Pressure is the force, created by a mechanical pump or by a water tower (weight of a column of water), which moves or pushes the water through the pipes and out the sprinkler nozzle or drip emitter orifice. Pressure is usually expressed as **pounds per square inch or psi.** Pressure also can be expressed as **Feet of Head** (height of a water column creating the pressure).

Pressure provides the force to push water through the nozzle opening to create the desired flow and desired distribution pattern on the ground. Nozzles work properly at some specified pressure and flow, gpm. Pressure creates the water stream that comes out of a nozzle to achieve the diameter of throw. Diameter of throw is the distance water is thrown out to form the outer perimeter of the water pattern.

Pressure is a force created by a mechanical device or by elevation (a 1 inch by 1 inch column of water as tall as the water tower or as high as the height between two parts of a pipe line has weight that creates pressure).

Pressure can be created by weight. Let's review some facts about water as they relate to pressure and volume. Then pressure will be defined in terms of weight onto a surface.

Facts:
Weight of one cubic foot of water is 62.4 pounds (lbs).
There are 7.48 (7.5) gallons of water in one cubic foot.
Weight of one gallon of water is 8.34 pounds.

One cubic foot of water is a volume of a box that is 1 foot (12 inches) wide by 1 foot deep by 1 foot high. One cubic foot has a base that is 12 inches by 12 inches or 144 square inches of area.

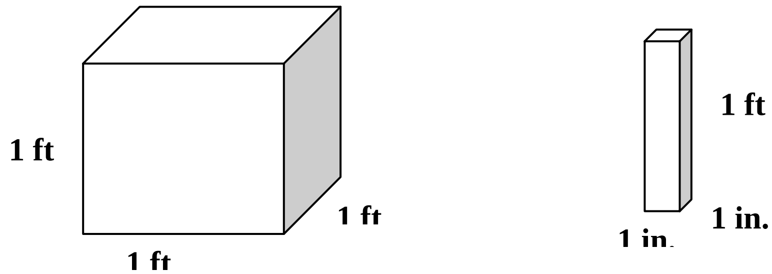
Pressure can be created by using the weight of the water.

One cubic foot of water (62.4 lb.) resting on the base of a cube (12 times 12 = 144 sq in.)

62.4 lbs. divided by 144 sq in. equals 0.433 pounds (weight) per square inch (area).

Thus, **one foot of water creates a pressure of 0.433 psi.**

One cubic foot is made up of 144 columns of water that are each 12 inches high. Each column has a base of 1 inch by 1 inch. This is another way to view the math above that says that each 1 inch by 1 inch column of water creates 0.433 psi pressure (Figure 3).



One cubic foot = 62.4 lbs. of water
Base of 144 sq. in.
Pressure = 0.433 lb. per sq in.

0.433 lb. of water
Base of 1 sq in.
Pressure = 0.433 psi

Figure 3 – Pressure is created by the weight of a column of water. Height, not volume, of water column causes the pressure.

A practical relationship for use in the field is what elevation change in feet causes 1 psi change in water pressure in a pipe line?

If 1 foot of water column = 0.433 psi, than how many feet is equal to 1 psi?
1 foot (of water) = 0.433 psi, divide most sides of equation by 0.433
1 foot / 0.433 = 0.433 psi / 0.433

2.31 feet = 1 psi

For each 2.31 feet of elevation change the water pressure changes 1 psi.

Perhaps the easiest way to learn about pressure is to look at how a water tower works. If we have a 1,000 gallon water tower with a full water level that is 100 feet above a faucet down at ground level, what is the water pressure at the faucet?

One way to express the pressure in this case is to say the pressure is equal to the weight of 100 feet of water on the ground surface or 100 feet of head. This is not very meaningful to most people so think about this. It is the weight of a column of water 1 inch by 1 inch by 100 feet tall pressing down on a 1 square inch of one's hand if you could hold up such a column.

We know from above that one foot of water creates 0.433 psi pressure. Now we have 100 feet of water column in the water tower. The water tower column creates 100 times 0.433 psi or 43.3 psi of static pressure (not flowing) at the bottom.

The next town has a water tower that is 100 feet high but it holds 40,000 gallons of water. What pressure does it create? Well, remember that volume was not a factor above. The value of 40,000 gallons of water over 1,000 gallons is that the level of the water in the larger tank will not drop as fast as the smaller one if water is drawn out quickly to fight a fire or to fill a tank truck. The same pressure is maintained longer with the larger tank (Figure 4).

Height, not volume, creates pressure. Each one foot of height is 0.433 psi of pressure.

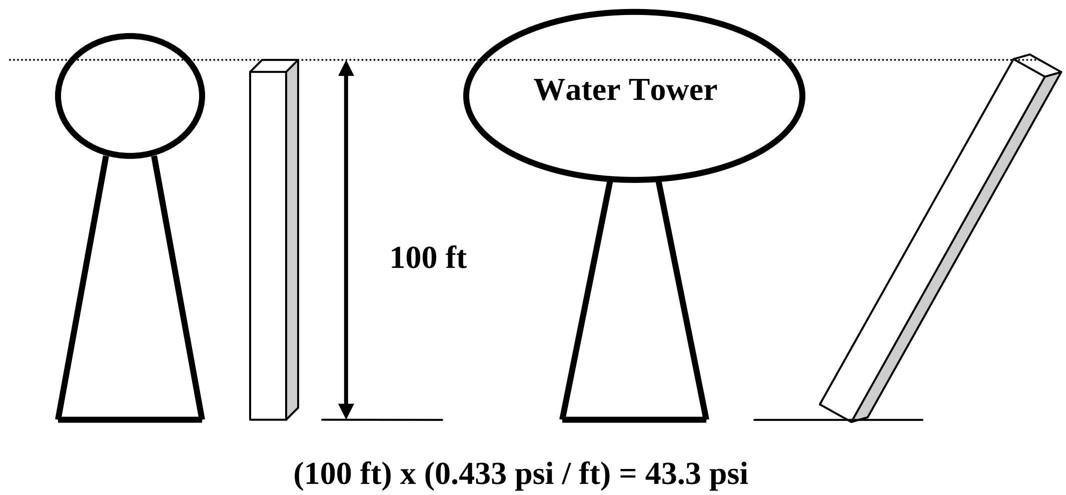


Figure 4 – The height, not volume, of water column determines the pressure.

The water does not have to be in a water tower. The same elevation (gravity) effect occurs in pipes running up or down the side of a hill. The static pressure difference between the top and bottom ends of the pipe will be equal to the feet of elevation change or feet of head. If the pipe has 40 psi at the bottom and its vertical rise is 10 feet, then the pressure at the top will be 40 psi – (10 feet rise x 0.433) = 40 – 4.3 = 35.7 psi (Figure 5).

Elevation changes cause pressure differences in pipe lines. Pressure decreases going up slope in a pipe line and pressure will increase going down slope in a pipeline. The change is 1 psi for each 2.31 feet of elevation change.

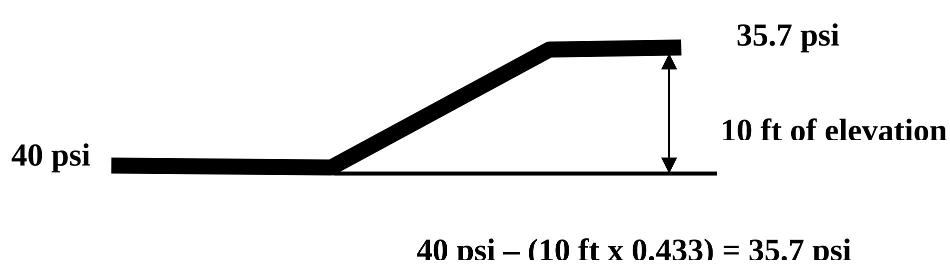


Figure 5 – Elevation change causes a change in water pressure in a pipeline.

This is a situation of static pressure (with no water flowing) in a pipe. If water is flowing from left to right, it is at 40 psi before flowing up slope 10 feet. We can calculate the pressure upslope knowing that 1 foot = 0.433 psi pressure change. This results in a pressure of 35.7 psi at the top of the rise.

When dealing with elevation in the field, a good relationship to remember is that for each 2.31 feet of elevation change, the pressure in a pipeline will change by 1 psi because of the weight of water in the pipeline. Going uphill, the water pressure will decrease and going downhill the water pressure will increase.

Remember these relationships for water pressure:
1 foot = 0.433 psi
2.31 feet = 1 psi

Pressure can also be created by a mechanical pump. Pumps are designed to pull water in by suction and to push it out against a column of water. A pump must hold a column of water up and continually add more water to the column. At the end of the system the pump is pushing the water through a sprinkler nozzle with enough force to break the water stream up into the right size of droplets to give a good distribution pattern on the ground. Along the way, there is a loss of pressure in trying to push water over pipe roughness. A pump must also move enough water (flow) to satisfy the requirements of the total number of sprinklers. There are many different designs for pumps in order to achieve the pressure and flow required for specific situations.

Water Flow

Flow in a system is dependent on the number of sprinklers or drip emitters being used at the same time. Each segment of a pipeline may have a different flow depending on the number of sprinklers or emitters there are on the segment. Water flows in a segment to escape through the outlet device – either a sprinkler or an emitter. Flow is commonly measured in gallons per minute (gpm) for sprinkler systems and gallons per hour (gph) for drip irrigation systems.

For example, let's have a system with a pump, a main line going to a field, and two lateral lines off the main line. Figure 6 shows sprinklers that operate at 5 gpm at 30 psi. Each segment of pipe must carry the water that is needed by the sprinklers beyond it. Thus, lateral A requires 20 gpm for four sprinklers but the flow decreases to 15 gpm after the first because the three remaining sprinkler nozzles will discharge a total of 15 gpm at 30 psi. Lateral B has only 3 sprinklers so it will discharge a total of 15 gpm. The two laterals together require 20 gpm plus 15 gpm for a total of 35 gpm. Thus, the pump must supply 35 gpm at 30 psi (No friction loss accounted for yet) to operate to operate the sprinklers properly.

The pump puts water (flow, gpm) into the pipeline and the sprinkler nozzles are the only places for water to exit so "flow in" must match "flow out". Flow at any point in a pipe line is equal to the sum of flow discharges (nozzle flows) beyond that point.

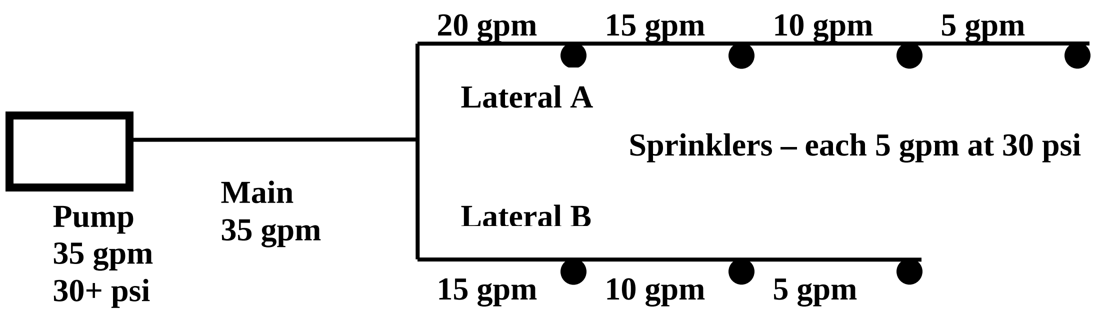


Figure 6 - Flow into a system must equal total discharged. Flow divides among sprinklers. Not shown here, actual flow from a sprinkler is dependent on actual pressure at that sprinkler.

Flow in pipe lines is the amount (volume) of water passing through the pipe per unit of time. Flow is commonly given as gallons per minute (gpm). Flow can be described in terms of pipe area and water velocity. The water passes through the cross-sectional area (square feet, sq ft) of a pipe at some velocity. Velocity is moving water at some speed measured in feet per minute (fpm). Multiplying these area and velocity terms together gives us a volume per unit of time, in cubic feet per minute. The common unit is gallons per minute so multiply by 7.48 gallons in a cubic foot to convert the flow into gallons per minute (gpm).

The equation that describes flow is:

$$Q = 7.48 \times V \times A$$

Where: Q = quantity of water flowing in gallons per minute (gpm)

V = Velocity of water given in feet per minute (fpm), in charts velocity may be given in feet per second (fps)

A = cross-sectional area of the pipe given in square feet (sq ft)

7.48 = conversion factor of 7.48 gallons of water per cubic foot.

Note that for a given flow, say 30 gpm, one could increase the pipe diameter (select a larger pipe size) and decrease the water velocity (slow the velocity) and still carry 30 gpm. Or, decrease pipe diameter and increase water velocity to maintain same flow. This is an important point to know.

Try to imagine flow in the following way. With a time clock in hand you instantaneously start the clock and turn on the valve to a long empty pipe line to start the water flowing. One minute later you stop the clock and turn off the valve. You have a section of water filled pipe. This is the volume of water that passed in that minute. You can empty that length of pipe into a bucket and find out how many gallons passed in one minute. This gives you gallons per minute (volume per time). Using the math equation above, you could also multiply the length of water-filled pipe (ft) times the cross-sectional area (sq ft) times 7.48 to get gallons per minute.

Friction Loss (Pressure Loss)

In our discussion of pressure so far the water has been **static** or non-flowing. When water is not moving, there is no friction loss and the pressure will be constant throughout the pipeline, except as elevation factors adjust the pressure. When water is flowing it becomes a **dynamic** situation and several factors come into play. **Pressure energy lost (friction loss)** is affected by several factors:

- Velocity of water flow. Faster the water flows, the more drag and turbulent in the pipe.
- Inside diameter of pipe (ID). Small flow must be faster in small diameter pipes.
- Roughness of material. PVC is smoother inside than standard steel. Less drag.
- Length of pipe. Friction increases with pipe length; it is accumulative.

Friction loss is a negative energy factor that must be taken into account so that it does not cause problems of non-uniform pressure and thus uneven water distribution over the crop. Friction loss is accumulative so pressure will drop along a lateral line of sprinklers. The last sprinkler operates at a somewhat lower pressure resulting in less water onto crops at the end of the lateral. This causes the grower to have to overwater most of the crop in order to get enough water onto the last plants on the lateral.

Friction loss is an energy loss (pressure loss) due to friction of the water against the surface of the pipe that is expressed as “psi per 100 feet” of pipe length.

Excessive friction loss can cause major problems of non-uniformity of operating pressure in an irrigation system so the crop can not be watered uniformly. Water is wasted, part of the crop is overwatered, and nutrients are leached away from the crop.

Friction loss increases with water velocity and designers caution about exceeding 5 fps in pipe lines due to potential damage if a valve is suddenly closed and the water mass must stop. High forces may be created. Also, a guideline on the amount of friction loss to accept is to not exceed 10 psi loss in a main line. There is an economic cost to over sizing pipes as well as a problem with non-uniform pressures if one under sizes a pipe. A designer must make choices.

Another consideration is future expansion. It is less expensive to install a larger pipe initially than to dig up and replace an undersized pipe if you start to outgrow your system.

Friction Loss Chart

The friction loss chart is very important tool to irrigation system designers for selecting the appropriate size of pipe to use for an application. It also can be used by a nurseryman to understand how a system works.

Pipe manufacturers and major irrigation equipment manufacturers provide charts that allow one to read the friction loss for different flow rates through different size pipes. This chart is used by irrigation system designers to select the pipe sizes to use. You can learn from studying the chart. Table 1 is a short version of a friction loss chart to illustrate its content. Only four pipe sizes of Class 160 PVC pipe are shown.

Table 1 - Friction loss for PVC Class 160 Pipe								
Pipe size (nominal) and actual inside diameter, inches								
Nominal	0.5		1		2		4	
Actual ID	0.720		1.195		2.193		4.154	
Velocity in feet per second (fps) and friction loss in (psi per 100 feet)[1]								
Flow, gpm	fps[1]	psi /100 ft	fps[1]	psi /100 ft	fps[1]	psi /100 ft	fps[1]	psi /100 ft
1	0.8	**0.20**[2]	0.28	0.02				
2	1.6	0.75	0.57	0.06				
3	2.4	1.56	0.85	0.14				
4	3.2	2.68	1.14	**0.23**[2]				
5	4.0	4.04	1.42	0.35				
6	4.8[3]	5.76	1.77	0.49				
7	5.6	7.66	1.99	0.66				
8	6.4	9.78	2.28	0.84				
10			2.85	1.27	0.84	0.07		
16			4.57[3]	3.04	1.35	0.16		
20			5.71	4.59	1.69	**0.24**[2]	0.47	0.01
40			11.42	16.59	3.39	0.86	0.94	0.04
55					4.66[3]	1.56	1.30	0.07
80					6.78	3.12	1.89	0.14
100					8.48	4.72	2.36	**0.21**[2]
130							3.07	0.34
200							4.72[3]	0.76
225							5.31	0.95

[1] Water velocities are given in feet per second here. Note the pipe area stays constant for each pipe size and velocities change to give increasing flow rates. Friction losses increase with velocity.

[2] Note that friction losses are about the same for the values footnoted (0.20 to 0.24 psi/100 ft). This illustrates the effect of the diameter squared term in the flow equation. Doubling the pipe diameter results in four times the flow rate.

[3] Water velocities (see the first column under each pipe size) are limited to a maximum of 5 feet per second (fps) (marked in the table by an underline) to avoid destructive water hammer inside the pipe. Water hammer can occur when valves are closed suddenly causing high pressure and a reversal of water flow direction. Use larger velocities with caution.

Note that in small pipe sizes, the friction loss increases quickly because the turbulent water flow is close to the pipe walls but the entire flow is much more affected than in larger pipe sizes where most of the flow is away from the walls in the middle of the pipe. Friction loss values do not get very larger in the larger sizes.

To use the chart, use the following pipe selection examples and the following procedure:

Example: Find the friction loss for 100 ft length of Class 160 PVC pipe, 1 inch diameter, carrying 6 gpm.

1. Find the flow rate of 6 gpm in the left column under Flow, gpm. Go right.
2. Find the 1 inch pipe size columns (Velocity and Friction) under pipe size at the top. Go down.
3. Find the chart location where these lines cross. Read 0.49 psi/100 ft.
4. Answer is – the friction loss is 0.49 psi per 100 ft of pipe.

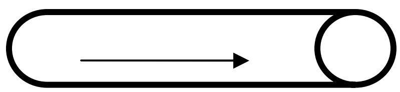
Example: Find the correct size of Class 160 PVC pipe to carry 20 gpm for 300 ft.

1. Find the desired pipe flow of 20 gpm in the left column. Move right.
2. Choices to the right include three pipe sizes.
   1 inch pipe at 4.59 psi per 100 ft, meaning 13.8 psi loss for the distance
   2 inch pipe at 0.24 psi per 100 ft, meaning 0.72 psi loss for the distance
   4 inch pipe at 0.01 psi per 100 ft, meaning 0.03 psi loss for the distance
3. Note that footnote 3 cautions one about exceeding 5 fps (300 fpm) water velocity. So that footnote, and the general rule that pressure losses should not exceed 10 psi in main lines, the 1 inch pipe is not a good choice. It is near its limit.
4. The 2 inch pipe has a safe velocity and reasonable friction loss. The 4 inch would also work but would cost a lot more.
5. This is a more complicated problem but illustrates several points. Use 2 inch pipe.

There are four factors that affect friction loss in pipes; they are reviewed here. Two of the four on illustrated below. The four factors are:

1. **Velocity (flow rate).** Velocity is the speed at which water moves through the pipe system. It is measured in feet per minute or in feet per second. **As the velocity increases, friction loss also increases.** Figure 7 illustrates what happens in a 1 inch Class 160 PVC pipe when the flow is changed from 5 gpm to 10 gpm. Note that increasing the flow has caused the water velocity to increase from 1.42 fps to 2.85 fps. This faster velocity changes the friction loss (pressure loss) from 0.35 psi / 100 ft of pipe to 1.27 psi / 100 ft of pipe. Doubling the flow has increased pressure loss more than 3.6 times.

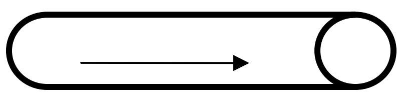
5 gpm 1 inch Class 160 PVC



Velocity = 1.42 fps

Pressure Loss = 0.35 psi / 100 ft of pipe

10 gpm 1 inch Class 160 PVC



Velocity = 2.85 fps

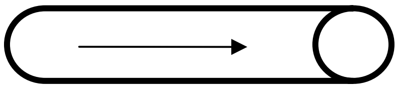
Pressure Loss = 1.27 psi / 100 ft of pipe

As Velocity increases (greater flow), friction loss also increases.

Figure 7 – As the velocity (flow) increases in a pipe (from 5 gpm to 10 gpm), the friction loss increases.

2. **Inside Diameter.** The second factor that affects friction loss is the inside diameter (ID) of the pipe. Decreasing the pipe size (with a constant flow) will increase pressure losses. Figure 8 illustrates this by replacing a 2 inch Class 160 PVC pipe with a smaller 1 inch Class 160 PVC pipe. The same flow of 16 gpm is maintained. In the 2 inch pipe the velocity was 1.35 fps and the pressure loss was 0.16 psi / 100 ft of pipe. Now the velocity is 4.57 fps (near the limit of 5 fps) and the pressure loss is 3.04 psi / 100 ft of pipe. Note the inside diameter (ID) of the pipe changed from 2.193 inch to 1.195 inch in the change. A decrease in pipe size (with constant flow) will increase the pressure loss.

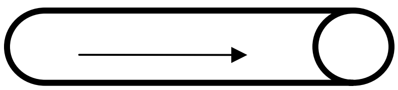
16 gpm 2 inch Class 160 PVC



Velocity = 1.35 fps

Pressure Loss = 0.16 psi / 100 ft of pipe
2.193 ID

16 gpm 1 inch Class 160 PVC



Velocity = 4.57 fps

Pressure Loss = 3.04 psi / 100 ft of pipe
1.195 ID

A decrease in pipe size (with constant flow) will increase pressure loss.

Figure 8 – A decrease in pipe size (constant flow) will increase pressure loss.

3. **Roughness of inside surface.** In a reference book showing the friction loss of many types of pipe there is also a roughness factor C assigned to pipe materials. The smoother the inside surfaces, the higher the C number. For example, PVC pipe has a C = 150 because it is smoother inside that steel which has a C = 100. Polyethylene and copper both have C = 140. **An increase in roughness (smaller C) increases the pressure loss.**

4. **Length of the pipe.** The last factor is the length of the pipe line. Friction loss is given as "psi / 100 ft of pipe" so the loss is accumulative. **The longer the pipe line the greater the pressure loss.** This is true of all sizes and types of pipe.

Comparing Flow in Different Pipe Sizes

The second footnote in Table 1 illustrates an interesting fact that one might use in considering pipe selection (or for having fun with a friend). The equation for flow is Flow = Pipe cross-sectional area (sq ft) times water velocity (fpm) times 7.48 to convert it to gpm. The area is the area of a circle or $A = \pi r^2$, where r is the radius of the circle and $\pi = 3.14$ (a constant) or $A= (D/2)^2$, where D is the diameter of the circle.

One can use this simple relationship to compare two pipe sizes. In this comparison we consider the velocities to be the same so the velocity component cancels out. The ratio of $(\text{area})_1 : (\text{area})_2$ becomes $(D_1)^2 : (D_2)^2$ when like terms cancel out. We can compare the nominal diameters squared for an idea of magnitude of difference in the water carrying capacity of two pipes. This comparison would be better if the actual inside diameters are used, as in Table 2.

So, how does a 4 inch pipe compare to a 2 inch pipe on amount of flow?

$$(D_1)^2 : (D_2)^2 = (4)^2 : (2)^2 = 16 : 4 = 4:1$$

By this quick estimate, a 4 inch pipe carries 4 times as much as a 2 inch pipe at the same velocity.

Table 2 shows the numbers taken from Table 1. Note that the flows roughly follow the **"double the diameter, quadruple the flow rate" rule.** The simple comparison is not exact using the nominal diameter, but is close enough for a guesstimation (for fun!).

Table 2. Pipe Size versus Flow Rate, gpm[1]	(Class 160 PVC pipe)
Pipe size, inches	Flow rate, gpm
0.5	1.0
1.0	4.0
2.0	20.0
3.0	55.0
4.0	100.0

[1] Flows are at roughly the same friction loss of 0.21 to 0.24 psi per 100 feet of pipe length.

Pumps

Pumps are designed to achieve some combination of a water flow rate and a working pressure. It takes power to move water or to create more pressure. To select the proper pump one must know two pieces of information:

1) water flow rate, and
2) total pressure head required.

Pump charts are available for matching requirements and finding an optimum efficient pump.

Example. Select a pump for an irrigation system that has 8 sprinklers. Each sprinkler will discharge an average 5 gpm. Water is from a well where the water level is 45 feet below the surface. The field to which the water is being pumped is 35 feet above the pump. The sprinklers will operate at an average of 50 psi and the friction loss is an average of 10 psi in the system.

Answer: If we have 8 sprinkler nozzles discharging 5 gpm each, then we must have at least 8 x 5 or 40 gpm of water from the pump. The pump must achieve the following pressure heads:

Lift water from the well	=	45 feet	
Push water up slope to field	=	35 feet	
Create 50 psi to operate sprinklers	=	115.5 feet	(2.31 x 50)
Overcome friction loss in pipes	=	23 feet	(10 psi was stated)
Total Pressure head		218.5 feet	(95 psi)

The total pressure head is the sum of all work the pump must do to supply the water. The work is the sum of lifting the water from the well (static suction head) + pushing the water up a hill (static elevation head) + operating pressure of sprinklers (operating head) + friction loss when water is flowing (friction head). This sum is the energy required to delivery the water.

To recap, a pump is selected to satisfy two criteria: a) the pump must move some amount of water flow, gpm, and b) the pump must provide the force to lift or push water. A dealer takes these two pieces of information and looks for the proper pump.

Have we mentioned **horsepower** yet? No! After the correct pump is selected, then the proper power supply must be found. A power unit, and its transmission if it has one, is not 100% efficient and the efficiency must be taken into account. Therefore, a pump may need 1 hp to operate it but, with the efficiency factor, it might take a 2 hp power unit to provide the 1 hp to operate the pump.

Practical Application of Knowledge on Pressure and Flow

Pressure. Pressure is the force created by a pump or by elevation (gravity) that moves the water through the pipeline and forces water out a nozzle or emitter at some predetermined rate based on the pressure and size of the nozzle or drip emitter opening.

Friction Loss. Friction Loss is an energy loss due to the water flowing over the rough surface of the inside of the pipe. Friction loss must be considered when sizing a pipeline and is a factor in the uniformity of pressure within an irrigation system. High water velocities result in high friction losses for a given size pipe. High friction losses in a lateral pipe mean a greater non-uniformity of application of water around the lateral irrigation line. Water velocities should not exceed 5 feet per second for most applications due to potential water hammer in the pipe.

Pressure Gauge. A key management and maintenance tool is the pressure gauge. When a system is designed it has a specific pressure at which it will operate for a given flow rate. This number should be posted next to the pump. If any of the irrigation zones are designed to operate at another pressure then that should also be posted. A variation might be due to a different flow rate within the range of the pump. This is the baseline pressure for the system.

The pressure gauge is then used to:

1. Check the pump to see if it is producing the correct pressure.

2. As an indicator that too few lateral lines are turned on. A high pressure will indicate fewer nozzles are discharging so the flow is less and pressure is higher.

3. As an indictor that too many lateral lines are turned on. A low pressure will indicate extra nozzles are discharging so the flow is high and the pump can not build up pressure.

If the pressure is off the original value, the pump may be wearing and water is slipping pass its pistons or centrifugal blade. Or, the nozzles may be wearing so that the orifice is larger and more water can escape.

The pressure gauge is an important monitoring tool for evaluating the operation of an irrigation system.

Sizing Pipe. Selecting the proper size pipe might be best left to the dealer who knows how to figure out all the pressure heads and how to use friction loss charts for selecting pipe sizes. However, after studying this chapter one is better equipped to ask questions about pressure losses and their effects on system functionality. A larger pipe size will cost more money but the larger pipe will carry more water at a lower energy loss. Give it some thought. Will the system be expanded in the future? Will uneven pressures occur if a smaller pipe size is used? Pressure uniformity helps to achieve water application uniformity. In the total cost of the installation, will the larger pipe cost a lot more?

Water Flow Meter. A water flow meter, both an instantaneous reading of current flow rate and a recording of accumulated flow, is also a good management and maintenance tool. Again, a new irrigation system was designed to discharge a specific flow rate of water in each lateral. Posting this information and monitoring with a water meter gives an indication that the system is functioning properly. Too much water flow might mean too many laterals are operating or that a break has occurred in a pipeline. Too little flow might indicate too few laterals are operating or that the pump is wearing.

For those holding a Maryland state water permit, a meter provides the information on water use that must be reported.

Check the Application Uniformity of Sprinkler Irrigation

If properly designed, a single irrigation lateral installed down the center of a bed of nursery containers will do a fair job of applying water. It is difficult to use devices that make a round tapered pattern fit well onto a rectangular growing bed.

A designer must set the sprinkler heads close together for more overlap and must size the lateral pipe so that the pressure loss (variation) is not more than 10 percent from one end to the other. This 10 percent variation will still mean as much as a 20 percent variation in water applied.

Since nursery crop containers depend on irrigation water this is not a place to use too small a pipe diameter. Application uniformity is critical to successful water and nutrient management. It costs more money to pump extra water to overwater one end of a bed in order to get enough water to the other end. Also, overwatering one end causes leaching which flushes the nutrients out of the container, costing dollars to manage the nutrients in the runoff.

A pressure gauge can be installed at both ends of a lateral to give one an idea of the pressure uniformity.

Straight sided containers can be placed across the nursery growing bed in two or three rows to catch the irrigation water. Measure and record the water from each container onto a chart to get an idea of the uniformity of application lengthwise and crosswise on the bed. This information will also give the time necessary to apply a given depth of water. This information will be useful in scheduling irrigation. This does not outline a complete audit procedure but suggests a quick way to check uniformity of application.

Summary

1. The purpose of this chapter was to acquaint the reader with pressure and flow in an irrigation system.

2. The issue of friction loss complicates the process of system design because you must balance the cost of a pipeline (the size of pipe used) and the pumping energy with the capability of delivering water uniformly.

3. The goal for irrigating container crops should be to deliver water uniformly so that containers are adequately wetted without excessive leaching.

4. Nutrient management is really water and nutrient management when containers are involved.

5. Nursery and greenhouse irrigation systems should be well designed by a qualified irrigation designer. Care should be taken to question a low bid to be sure the application uniformity is not being compromised.

6. Pressure gauges and water meters are two important tools for monitoring an irrigation system and their use should be part of the management process.